



Technology Evaluation for Environmental Risk Mitigation Principal Center

Life Cycle Corrosion of Space Vehicles (Lab Testing) Project Number: NT-1309

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Background

There exists a desire to better understand the performance environments in which aerospace assets exist and how well coating systems are capable in those environments of protecting those assets from degradation. Protective coatings serve as the primary defense against corrosion of metallic alloys. Traditional coatings for aerospace vehicles include inorganic pretreatments, epoxy primers, and polyurethane topcoats. Pretreatments provide some corrosion protection and prepare the surface for subsequent organic coatings. Primers normally contain high concentrations of corrosion inhibitors, such as chromates, and are designed to provide superior adhesion and corrosion protection. Polyurethane topcoats are formulated to enhance protection and durability. More recently, alternative coatings have been developed, such as hexavalent chromate free pretreatments and primers and low volatile organic compounds (VOCs) containing coatings. These new developments reflect trends in protective coatings technology and concerns over environmental protection and worker safety.

The potential durability of coatings can be evaluated by numerous methods in the laboratory and the field. In the laboratory, ASTM B117 Salt Fog is the standardized test method used to check corrosion resistance of coated samples. Salt spray testing is popular because it is standardized and reasonably repeatable. The salt spray test is widely used in the industrial sector for the evaluation of corrosion resistance of finished surfaces or parts. The ASTM B117 Salt Fog test is an accelerated corrosion test that produces a corrosive attack to the coated samples in an effort to predict its suitability as a protective finish. The ASTM B117 procedure involves testing in a controlled corrosive environment that produces relative corrosion resistance information for specimens of metals and coated metals exposed in a test chamber. After a specified period of time, the test panels are removed from the test environment and evaluated for corrosion products. The test is effective in that conditions are actually more corrosive than typical "real world" exposures. This is because the test uses sodium chloride in de-ionized water, which usually lacks the moderating effects of other dissolved salts like those containing calcium and magnesium, which tend to be somewhat protective.

One criticism of the ASTM B117 Salt Fog test is that it does not represent real-world corrosion observations. Although ASTM B117 takes into account the time-effects of humidity, temperature, and salt exposure, it does not address the factors of ultraviolet light exposure, ozone exposure, and salt type. Additionally, conventional salt mixtures are not based on salts seen in atmospheric samples taken at KSC. Instead, they are a simple laboratory solution of sodium chloride. Lastly, most industrial areas have measurable levels of ground level ozone, and KSC is no exception to this and conventional laboratory corrosion test environments do not include ozone as a factor.

In the field, the KSC Beachside Atmospheric Test Facility is an ideal location for testing the long-term performance of many materials in use at KSC and other locations around the world. However, testing coatings at this location is time-consuming. The objective of this project is to test coating systems as well as bare substrates and compare the performance and corrosion rates to those observed both at the Beachside Atmospheric Test Facility and at Launch Complex 39-B where coupons have been in place since November of 2008. Additionally, lab results will be compared to traditional B117 salt-fog testing of the same coating systems.

The laboratory test will consist of a 2k-factorial designed experiment with three factors, UV-light exposure, ozone exposure and salt type. High and low levels of light and ozone were chosen to be 800 ppb for the high and 100 ppb for the low for ozone and 96% for the high and 10% of the UV lights strength for the low.. The test cabinet has been developed as part of a larger Strategic Environmental Research and Development Program (SERDP) led by the Department of Defense. The object of this project is to begin the development of a comprehensive accelerated laboratory test protocol that will accurately predict all aspects of the performance of coatings. The hope is that a test protocol will be able to rank coatings independent of substrate and that it can be tuned to the expected performance environment(s) of the asset of interest.

Objective

Objective is to compare corrosion rate data and coating performance data for two hex-chrome free coating systems to real world exposures of the same variety by using a newly designed combined environment cabinet. The ability to more accurately predict coating performance in a specific environment based on an accelerated test is of great interest to the aerospace community. An additional goal is to compare lifecycle costs of hex-chrome systems vs. hex-chrome free systems taking into account costs of regulations and ever stringent occupational health requirements. Testing will leverage from currently ongoing Phase II TEERM Non-

Chrome Coating System Project by using coatings that have shown corrosion effects after six months exposure, and will compare corrosion rates for aluminum and steel substrates to those being exposed at the KSC Beachfront Corrosion Test Facility and Launch Complex 39-B. This project will also allow NASA TEERM to leverage from the follow-on testing of the novel combined environment cabinet being performed as a larger-scale SERDP project. Testing will be in the format of a 2k Factorial Design of Experiments test using UV-light, Ozone and Salt Type as factors. Lifecycle cost benefit analysis will be based on tested coatings and control coatings; it will primarily involve literature research and historic / known costs of current systems used within NASA as a baseline. Additional testing for the lifecycle cost portion will likely involve test panels that have undergone repair and rework to determine robustness of repairs -along with determining repair cycles for coating systems.

Period of Performance

- September 2009 to December 2011

Stakeholders

NASA Centers (Kennedy Space Center (KSC), Marshall Space Flight Center (MSFC); Constellation Program, Air Force Materials & Manufacturing Directorate and Wright Patterson Air Force Base Coatings Technology Integration Office, University of Dayton Research Institute Navy & Army, ATK, United Space Alliance, Battelle

Benefits

- Initial phase in development of improved test for qualifying hex-chrome free coatings for aerospace
- Better understanding of KSC's Environment and how it impacts corrosion of critical assets
- Reduce maintenance and depot costs for repair and rework of coating systems if better performance data can be determined.
- Reduced maintenance cost and government liability

Recent Progress

- Completed Initial Analysis of Results – May 2011

Document Status

- Included preliminary findings in Interim Test Report for Hex-Chrome Alternatives for Aerospace Project – May 2011

Milestones

- Began cabinet construction in August, 2009
- Finalized Test Plan on October 1, 2009
- Completed initial Combined Environment Test cabinet construction on October 9, 2009
- Completed cabinet modifications in November 2009
- Test panels prepared and shipped to WPAFB in November 2009
- Battelle supplied silver test panels received from Battelle for testing (in-kind) – October, 2009
- Test panels for 2k factorial experiment are prepared, awaiting initial testing of cabinet before proceeding to test – December 2009
- Analyzed simulated data and write draft report for lab testing – December 13, 2009
- XPS analysis and additional Liquid Chromatography was performed at UDRI – January 2010
- New sensors for test cabinet were ordered – February 2010
- Initial testing of completed Combined Environment Test Cabinet completed– February 2010
- First set of atmospheric exposed silver coupons sent to Battelle – March 2010
- Sensors installed – April 2010
- Solenoid valve for controls ordered and installed – May 2010
- Salt solution 1 (5% NaCl) stabilized in cabinet – June 2010
- Ozone controller out for calibration / repair – June 2010
- Second set of atmospheric exposed silver coupons sent to Battelle – June 2010
- Third set of atmospheric exposed silver coupons sent to Battelle – September 2010
- Testing started in Combined Environment Test Cabinet - September 2010
- Third set of atmospheric exposed silver coupons sent to Battelle – September 2010
- Started testing with the first setting of eight at UDRI – September 2010
- Received positive results for initial silver coupon from Battelle – September 2010
- Settings 1-4 with 5% NaCl were completed – November 2010

- Completed all tests with the 5% NaCl solution – November 2010
- Salt solution 2 (KSC simulated salt) stabilized in cabinet – November 2010
- KSC salt solution was manufactured in the lab successfully and was stabilized in the cabinet – November 2010
- Completed test runs 1-7 and a re-run of one setting – December 2010
- Completed 3 of 4 tests with the KSC atmosphere simulated salt solution – December 2010
- Fourth set of atmospheric exposed silver coupons sent to Battelle – December 2010
- Settings 5-7 with KSC salt solution were completed – December 2010
- Project testing expected to be complete by December 31, 2010
- Completed Combined Environment Testing – January 2011
- Setting 8 with KSC salt solution completed – January 2011
- Design of Experiments and Regression Analysis began – February 2011
- Began Analysis of Results – February 2011
- Completed literary research on lifecycle costs of using hexavalent chrome – May 2011

Future Goals

- Complete data analysis from combined environment cabinet testing and include in final report for Hex-Chrome Alternatives for Aerospace Applications – September 2011

Updated 07/01/11